



Department of Defense
Defense Safety Oversight Council

Reducing Vehicular Vibration and Impact Exposure Language for Acquisition Documents

Name
Title
Organization

Date



Overview

- Vibration and Impact Exposure
 - Whole-Body Vibration
 - Repetitive Impact
- Harm to the Warfighter
- Purpose of Quick Reference Guide
- How to use Quick Reference Guide



Whole-Body Vibration and Repetitive Impact

- **Whole-Body Vibration (WBV)**
The transfer of relatively low-frequency environmental vibration to the human body through a broad contact area such as the feet when standing, the buttocks when sitting or the entire body when in contact with a vibrating surface.
- **Repetitive Impact**
Transient mechanical shocks such as the jarring jolting, or slamming of high-acceleration events as opposed to the more steady state of vibration exposure.





Excessive WBV Exposure

- Exposure to WBV in DoD vehicles is a known entity but not fully understood; contributes to low back pain (LBP) and other performance-degrading conditions and injuries
- Reduces operational effectiveness and has a significant price tag for lost-duty days, medical treatment, and long-term care.

Technology exist to reduce WBV, but is often overlooked or not utilized in designs

- Seating systems designed with priority to crashworthiness, other considerations
- Mission durations exceed design considerations and standards for exposure limits
- Difficult to differentiate WBV role with other risk factors
- Large variability in response between individuals
- Addition of personal gear exacerbates ergonomic issues (NVGs, body armor, etc.)

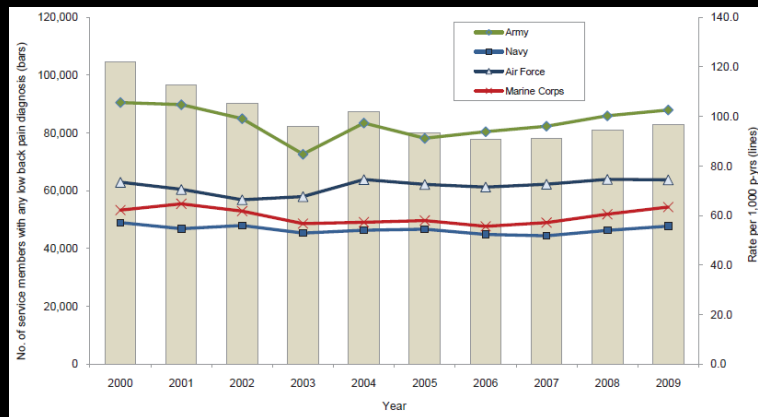




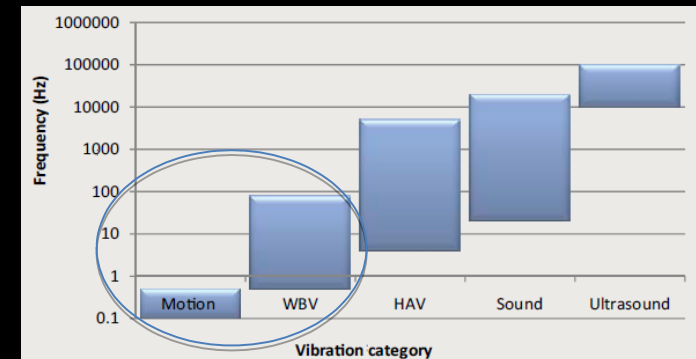
Harm to the Warfighter (WBV)

- Reduced mission capability:

- “Whole-body vibration (WBV) contributes to low back pain and is a major source of lost time in occupational environments.”¹
- “Low back pain (LBP) is among the most frequent causes of medical visits and lost-duty time in the U.S. Armed Forces.”²



Number and incidence rates of any mechanical low back pain diagnosis, by Service, active component, U.S. Armed Forces ²



Frequency Ranges of Concern ¹

“The medical health care and military operational costs of LBP are enormous. Interventions that could reduce the prevalence and recurrence of LBP could be extremely cost-effective and should be a high priority for military research”²

¹ Paschold, H.W. & Mayton, A.G. (2011, April). Whole-body vibration: Building Awareness in SH&E. *Professional Safety*. Retrieved from: www.asse.org

² Armed Forces Health Surveillance Center. Low Back Pain, Active Component, U.S. Armed Forces, 2000-2009. *MSMR*. 2010 Jun; 17(07):2-7.



Excessive Repetitive Impact Exposure

- Less subtle than WBV – higher magnitude accelerations
- The problems associated with exposure to excessive impact loads in DoD vehicles are relatively well-known; with serious consequences for operational effectiveness and a significant price tag for lost-duty days, medical treatment, and long-term care.

Systems are capable of operation in environment conditions which exceed human limitations

- Sea states
- Land terrains
- Speed
- Mission durations





Harm to the Warfighter (Repetitive Impact)

- Reduced mission capability:
 - Fatigue & Motion Sickness
 - Musculoskeletal Injuries
 - Degraded Performance & Effectiveness
 - Diminished Safety
 - Reduced Readiness



“Occupants of U. S. Special Operations high speed craft are exposed to severe and repeated shock loads during operation in heavy seas, leading to an alarming incidence of reported chronic and acute musculoskeletal injuries. Traditional craft design rules for craft seakeeping qualities are assumed to account for spinal impact injury.”¹

¹ Peterson, R., Pierce, E., Price, B., & Bass, C. (2004). *Shock Mitigation for the Human on High Speed Craft: Development of an Impact Injury Design Rule, RTO-MP-AVT-110*. North Atlantic Treaty Organization. Retrieved from www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA446789.



Purpose of Quick Reference Guide

- The Human Systems Integration Task Force, under the Defense Safety Oversight Council, has produced a Quick Reference Guide.
- This guide provides requirements writers and reviewers, Program Managers (PMs), System Program Office (SPO) personnel, Human System Integration (HSI) practitioners, and other acquisition personnel with a useful desktop reference for developing program-specific language for acquisition documents; aimed at reducing harmful vibration and impact exposures in new and existing DoD vehicle systems.



Why the Acquisition Process is Key

- The acquisition process is the key point within a system's lifecycle in which to consider WBV and repetitive impact exposure.
- The earliest and most direct method of influencing a new system is to address issues in acquisition process, documents.
- Equipment should be designed and engineered to produce and transfer less WBV and impact energy to the warfighter, and existing equipment should be modified with mitigation technologies where necessary and feasible.

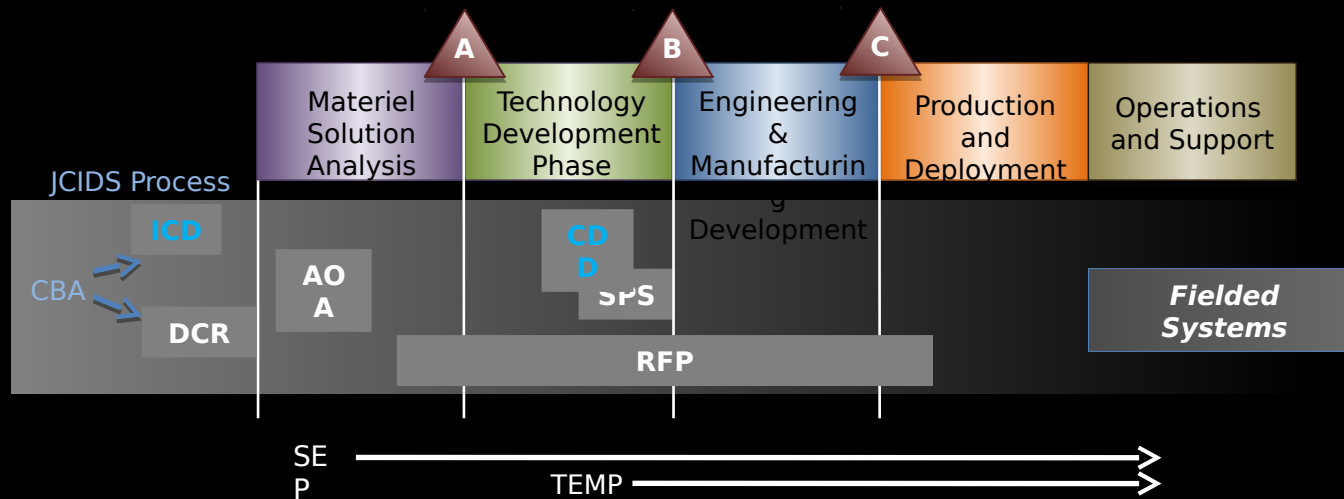


Targeted Documents and Processes

- Acquisition documents targeted for WBV and impact exposure language:
 - DOTmLPF-P Change Recommendation
 - Initial Capability Document (ICD)
 - Analysis of Alternatives (AOA)
 - Capability Development Document (CDD)
 - Systems Engineering Plan (SEP)
 - Test & Evaluation Master Plan (TEMP)
 - System Performance Specification (SPS) or System Requirements Document (SRD)
 - Request For Proposal (RFP)
- Ideas for Existing Systems (fielded/legacy systems)
 - Modification process suggestions
 - Service-specific guidance for systems modifications



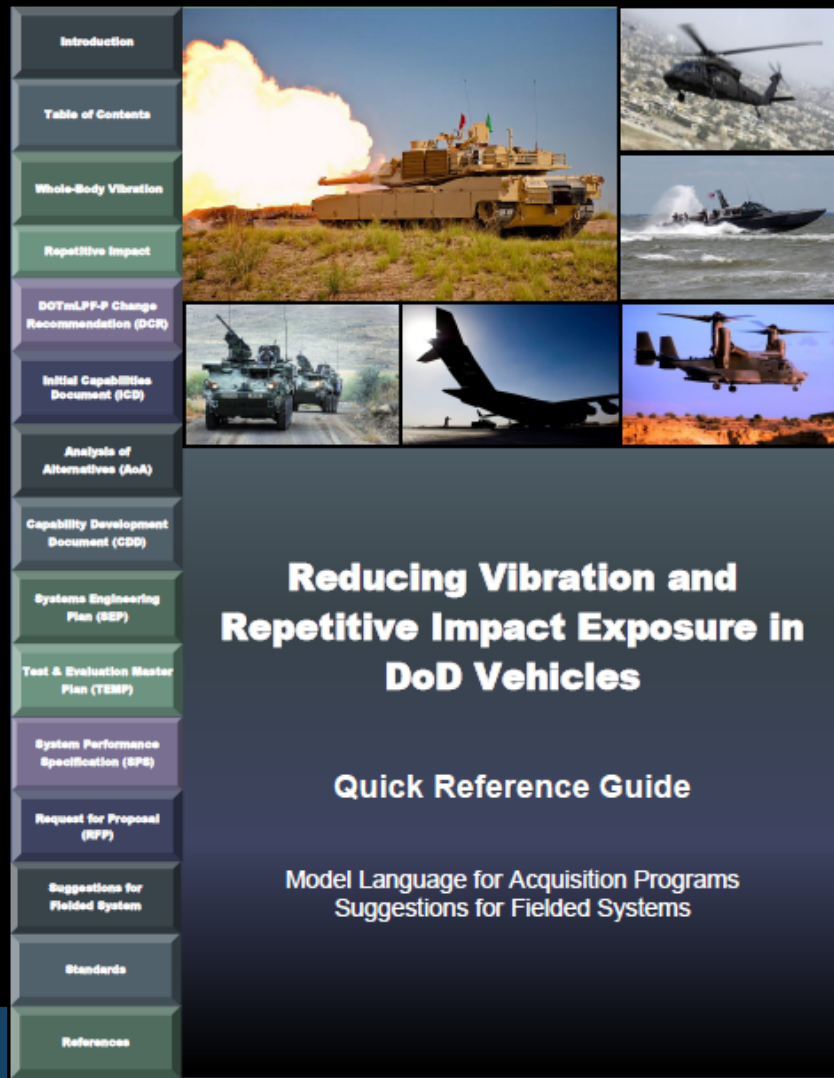
Targeted Documents and Processes



- **DCR:** Recommendations for changes to existing resources when not associated with a new defense acquisition program
- **ICD:** Documents one or more new capability requirements and associated capability gaps
- **AOA:** Analytical comparison of alternatives that satisfy established capability needs
- **CDD:** Defines measurable, and testable parameters across one or more increments of a materiel capability solution
- **SEP:** Details actions that outline all technical aspects; HSI planning, Human Factors Engineering, etc.
- **TEMP:** Documents the overall structure and objectives of the Test & Evaluation (T&E) program
- **SPS:** Translates required warfighter capabilities into system/subsystem acquisition requirements
- **RFP:** Used in negotiated acquisition to communicate government requirements to prospective contractor and solicit proposals



How to Use the Quick Reference Guide



Linked .PDF organized by:

- Introductory information
 - WBV
 - Repetitive impact
 - DoD Standards Intro
- Selected documents sections with example language and guidance
- Section with suggestions and guidance for fielded systems
- Standards & References



How to Use the Quick Reference Guide

What is Whole-Body Vibration?
What is Repetitive Impact?

Home

Whole-Body Vibration

Whole-body vibration refers to the transmission to the human body of low frequency environmental vibration typically in the range of 0.5 to 80 Hz through a broad contact area, such as the feet when standing, the buttocks when sitting, or the reclining body when in contact with the vibrating surface (www.vibrationdirective.com).



WBV is typically measured in a three-axis coordinate system. The axes represent vibrations as fore and aft (x-axis), side to side (y-axis), and vertical (z-axis).

The transmission of WBV to the human body at the natural frequency of the body as a whole or of its individual parts will result in resonance (an amplification of the vibration). In response, muscles will contract in a voluntary or involuntary manner and cause fatigue or a reduction in motor performance capacity (Paschold, 2011).

Many studies conclude that regular exposure to whole-body vibration can lead to back and neck pain and even musculoskeletal damage. The longer an individual is exposed and the higher the magnitude of the vibration, the greater the chances of injury.

Figure 2: WBV Body Image

Repetitive Impact

Repetitive impact refers to transient mechanical shocks such as the jarring and jolting of multiple high-acceleration events, as opposed to the more steady state of vibration exposure (Martin et al. 2008).

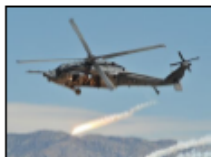
A mechanical shock is a non-periodic disturbance characterized by suddenness and severity with, for the human body, the maximum forces being reached within a few tenths of a second, and a total duration of up to about a second (Brammer et al., 2004).



Adverse effects to the lumbar spine are the dominating health risks of long-term exposure to vibration containing multiple shocks (ISO 2631-5, 2004).

Vibration and repeated impact loads transmitted to the human body can reduce comfort, increase fatigue, cause injury, interfere with effective performance, and influence operational safety.

Prolonged exposures can increase the potential for debilitating acute and chronic spine injury and other musculoskeletal injuries.



Easy navigation (user can quickly navigate back to cover page)

Background information on WBV and Impact



How to Use the Quick Reference Guide

Capability Development Document (CDD)

Home

Capability Development Document (CDD)



The suggestions, example language provided, and the placement of the language within the document(s) are presented as a reference for acquisition and other professionals. Examples are not necessarily meant to be specific for any particular type of system or acquisition program. Suggestions and examples provided are intended to assist acquisition professionals by providing a starting point for tailoring language unique to individual development programs. Specific standards can be obtained from an HSI practitioner or from any of the sources identified in the Standards and/or References tab.

The purpose of a CDD is to provide traceability to predecessor documents. It defines authoritative, measurable, and testable parameters across one or more increments of a materiel capability solution, by setting Key Performance Parameters (KPPs), Key System Attributes (KSAs), and additional performance attributes (description, objective, threshold, and analytical references) associated with specific capability solution(s). It also identifies related DOTMLPFP impacts of each proposed capability solution.

CDD Model Language for Whole-Body Vibration (WBV) and/or Repetitive Impact

This section provides model language (examples / statements) to address WBV and/or repetitive impact. Information in the form of Section Notes or Guidance may be provided which is generally applicable to the CDD Section identified. These sections may include Example Tables or other information (with WBV / Impact examples), presented in a CDD-representative format.

The examples and formats provided will vary, in order to present the user with broad options and a general starting point for a CDD intended to incorporate WBV and/or repetitive impact as an important attribute(s). The user of this Guide is reminded that the information provided is intended to assist in "crafting" or "tailoring" language most appropriate to their particular program or set of circumstances, not to be a direct "cut-and-paste" solution.

- KEY -	
<...>	"Insert Applicable Information Here" (i.e. <P>, <O>, <Y>, <Z>, etc.)
<name, value, other>...	Same as Above with category or example of information needed
6_...G-x	Placeholder: example "unique identifier" for example language

Table 8: CDD Section

Document Section	Section Notes / Guidance
No Notes / Guidance for this section	
Document Section	Example Language
CDD Section 2 Analysis Summary Or "Alternate" CDD Format Section N/A	• <Existing systems> are consistently utilized in environments (extreme terrains) for which the crew systems were not intended to or designed to support (creating ride environments and exposures beyond human physical limitations for safety, health, performance, comfort (IAW MIL-STD-1472G, MIL-STD-882E); adapted mission profiles outside original system employment CONOPS, and Command AOR). • <existing systems, legacy systems> are consistently utilized in extreme environments, for durations in which the crew seat/interface systems (seat ergonomics, seat support, seat padding, seat vibration/impact damping, and combination) were not intended for or originally designed to support (creating ride environments and exposure conditions beyond human physical capabilities/limitations for safety, health, performance, comfort (IAW MIL-STD-1472G, MIL-STD-882E); adapted mission profiles outside original system employment CONOPS, and Command AOR). • In <o> environments, <existing systems> produces excessive system (mechanical) vibration with additional environment-produced vibration energy which is transferred to crew stations, crewmembers, and passengers through human-system interface (seats, floor, controls).

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Educates on selected document

Multiple language examples for sections within each document represented in the guide.

Document Section	Section Notes / Guidance
No Notes / Guidance for this section	
Document Section	Example Language
CDD Section 3 CONOPS Summary Or "Alternate" CDD Format Section 1 Executive Summary	• In order to meet required <system> human systems integration <WBV / impact> considerations with non-materiel only solutions/alternatives (existing systems and capability requirement gaps (see DOTMLPFP analysis)), changes to legacy system employment CONOPS or system use-case strategies may be required (to mitigate safety and health issues with crew/seater exposure to WBV and/or repetitive impact (shock) with legacy system design and employment strategies). • Non-materiel changes include (for legacy/existing system employment): personnel-training and preventative physical fitness measures, manpower increase-crew rotation, mission duration limitations, use-case stipulations based on environment/conditions).
Document Section	Section Notes / Guidance
CDD Section 6 Dev. KPPs, KSAs, Additional Performance Attributes Or "Alternate" CDD Format Section 5 Dev. KPPs, KSAs, etc.	• The below section gives an example "unique identifier" along with the example language statements. • Cite MIL-STD-1472G, Section 5.5.5, and referenced standards as contractual requirement where appropriate (to support KPP, KSA, Other (T-Threshold) (O-Objective) requirements and verifications). • References: MIL-STD-1472G, ISO 2631-1; 1997 and ISO 2631-5; 2004
Document Section	Example Language (Air Vehicles)
6_...A-x	The <system name> shall be designed to minimize system vibration and to mitigate or control the transmission of whole-body vibration to crewmembers and passengers to levels <insert Threshold, insert Objective> that permit safe and effective operation as specified in MIL-STD-1472G section 5.5.5., ISO 2631-1; 1997 (magnitudes and durations of exposure) <Define (T) and (O)>.
CDD Section 6 Dev. KPPs, KSAs, Additional Performance Attributes Or "Alternate" CDD Format Section 5 Dev. KPPs, KSAs, Additional Performance Attributes	Rationale: MIL-STD-1472G and associated Standards defines the safe whole-body vibration exposure ranges for personnel spaces and human interfaces. The <existing system> interface systems <seats, floor space, control surfaces, other> are considered insufficient or do not meet standards.
6_...A-x	The <system name> shall be designed to control the transmission of system and environment-induced repeated impact energy (a.k.a. shock) to levels that permit safe and effective operation per MIL-STD-1472G section 5.5.5., ISO 2631-5; 2004 (magnitude and durations of exposure) <Define (T) and (O)>.
CDD Section 6 Dev. KPPs, KSAs, Additional Performance Attributes Or "Alternate" CDD Format Section 5 Dev. KPPs, KSAs, Additional Performance Attributes	Rationale: MIL-STD-1472G and associated Standards defines the safe repetitive impact exposure ranges for personnel spaces and human interfaces. The existing <system> interface systems <seats, floor space, control surfaces, other> are considered insufficient or do not meet standards. The <existing system> interface systems <seats, floor space, control surfaces, other> are considered insufficient or do not meet standards.
6_...A-x	The <system> seat(s) or seating systems shall promote good posture in the operational environment and for the duration of the mission by providing uniform body support over the seat-occupant contact area (not causing "hot spots" to occur), not transmitting vibrations to the occupant of <o> frequencies exceeding <o> amplitudes, and providing back support to reduce lumbar loads and back muscle fatigue.
(Air Vehicles)	Rationale: MIL-STD-1472G defines personnel spaces based on human factors engineering. The <existing system> seating systems do not meet this requirement.

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How to Use the Quick Reference Guide

Fielded Systems

Home

Suggestions for Fielded Systems (Reducing Vibration and Impact Exposure)



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During the life-cycle of weapons systems it is often necessary to make changes to their configurations for various reasons. Management procedures for making modifications to systems are based on whether the system to be modified is in development/production, or is out of production. For new systems and equipment, vibration may be best attenuated by vehicle and seating system design. Legacy systems may have the potential for vibration attenuation through improvements in seating design/modifications and stringent maintenance practices. This section (as well as that in the QRG) also provides some suggestions and references to Service-specific guidance for system modification programs/processes for systems outside of the normal acquisition process (such as legacy systems still in operation).

Background and Guidance on System Modifications:

Enclosure 2, Para 8.c.(2),(e) of DoD Instruction 5000.02 requires that "DoD Components shall initiate system modifications, as necessary, to improve performance and reduce ownership costs, as constrained by section 2244a of Title 10, US Code." In addition, Para E1.1.16, of DoD Directive 5000.01 entitled Performance-Based Acquisition directs that "to maximize competition, innovation, and interoperability, and to enable greater flexibility in capitalizing on commercial technologies to reduce costs, acquisition managers shall consider and use performance-based strategies for acquiring and sustaining products and services whenever feasible. For products, this includes all new procurements and major modifications and upgrades, as well as re-procurements of systems, subsystems, and spares that are procured beyond the initial production contract award" (Defense Acquisition Guidebook).

Some suggestions/ideas include:

Exercise DOTMLPFP Analysis / DCRs (including Materiel - "little m")

- Implement non-materiel recommendations
- Recommendations for Command, Unit-level vehicle-specific improvements (e.g. crew station systems – active/passive vibration isolation damping, improved posture supports, etc.)
- Non-acquisition – replacement seating pads with vibration damping and improved posture support (existing technology, no system modification, by vehicle/platform)
- Commercial Off-The-Shelf (COTS)/Commercial and Non-Developmental Items (CANDI) – purchase seat appliances/pads with vibration isolation/damping technology, posture improvement, etc. for a particular vehicle/platform

Engineering Change Proposal (ECP)

- Incorporate new requirements within existing or ongoing acquisition program (can be very expensive)
- ECP or during scheduled Depot or servicing rotation
- ECP during "block upgrades"

Deficiencies Corrected / New Requirements Incorporated into:

- Service and platform-specific Recapitalization Programs (Recap)
- Service Life Extension Programs (SLEP)
- Other legacy system modification/upgrade program, or "pre-planned product improvements"

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Provides suggestions for addressing WBV/Impact in fielded systems

Service-specific guidance for modification efforts

Utilize Service-Specific Modification Programs and Procedures

- US Air Force USAF, AFM 63-131, Modification Management Program

Example: AF Form 1067 Modification Proposals

Need and Authority (Para 8.10.1.1)	Justification/Support Authority (as determined by Validation Authority)	Approval Authority (as determined by Validation Authority)
Less than \$100K	Less than \$100K & P10	If validated as Permitted "Modifications" as Permitted (1, 2, 3) and 100K requires use of AF Form 1067
Between \$100 - \$100K	\$250K	If validated as Permitted "Modifications" AND less than 100K of AF Form 1067 is required (over 100K - 100K is required)
More than \$100K	AFMOC and AFMOC	AFMOC, needs to develop new DCRS Document(s) for appropriate approval/validation

USAF, AFM 10-601, Chapter 8, Requirements Activities to Support Modifications
USAF, AFM 63-1101, AMC Sup 1, AFMOC 63-1101, AFMOC 63-1101

- US Navy USN, SECNAVINST 5000.2E Department of the Navy Implementation and Operation of the Defense Acquisition System and the Joint Capabilities Integration and Development System
USN, SECNAVINST 4855.5 Product Quality Deficiency Report (PQDR) Program
- US Army USA, AR 750-10, Army Modification Program
USA, AR 752-7-1, Reporting of Product Quality Deficiencies
USA, AFM 74-6, Product Quality Deficiency Report Program



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Questions?